

The University of Chicago

LAND UTILIZATION IN
THE CANÓVANAS SUGAR DISTRICT
PUERTO RICO

A PART OF A DISSERTATION SUBMITTED TO
THE FACULTY OF THE DIVISION OF THE
PHYSICAL SCIENCES IN CANDIDACY FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF GEOGRAPHY

1937

By
MARGUERITE UTTLEY

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LAND UTILIZATION IN THE CANOVANAS
SUGAR DISTRICT, PUERTO RICO

Nature of Investigation

General Aspects of the District

San Isidro Land Type, the Stronghold of Cane

- General characteristics
- Suitability of soil for cane culture
- Drainage problems
- Agricultural techniques
- Danger of floods
- Transportation of cane
- Major uses of the land

Hato Puerco Land Type, the Second-rate Cane Lands

- Status in the cane belt
- Soil cover on the slopes
- Cultivation of the slopes
- Hazards of drought and hurricane

Luquillo Land Type, the Poverty Zone for Cane

- An area of "chronic crisis"
- Outliers in the coastal lowland
- Cultivation of mountain slopes
- Occupance by subsistence farmers

Hacienda Grande, the Frontier of Cane Occupance

- Recent reclamation of swamp areas
- Drainage works
- Special methods of cane culture
- Soil characteristics and cane yields
- Utilization of undrained areas

Loiza Land Type, the Inhospitable Ground for Cane

- Insignificance in the cane belt
- Suitability for coconuts versus sugar cane
- Relation of coconut groves to cane lands

Prospects of the Sugar Industry in the District

Nature of the Investigation

This study is concerned with the Canóvanas district, one of the thirty-four sugar-producing units¹ which rim the mountain core of Puerto Rico. It is in the northeastern corner of the island, about fifteen miles from San Juan (Fig. 1). The area here designated "the Canóvanas district" covers approximately fifty-two

¹In this study, the term sugar-producing unit designates a central (a mill which produces raw cane-sugar) and all the lands from which it obtains its supply of cane.



Fig. 1.--Location of the Canóvanas district. (Base map and contours from U. S. Forest Service, Map of Porto Rico and Contiguous Islands. Centrals operating in 1932 from Final Crop Report of the Association of Sugar Producers of Puerto Rico, Facts about Sugar, XVIII (1933), 368.)

square miles and includes all plantations and small cane farms tributary to Central Canóvanas. It also contains some land devoted to other crops and considerable tracts of uncultivated land. The areas planted to cane, totaling about 13,000 acres, give a high yield under intensive cultural practices. Cane dominates the agricultural landscape, occupying fully three-fourths of the cultivated area. However, when the district is viewed from a mountain side, the cane belt is seen as a narrow green ribbon following the upper margin of the plain, and sending frayed edges northward toward the sea and southward into the mountains (Fig. 2).

The Canóvanas district is typical of the sugar-producing districts on the north coast of the island in that it receives a rainfall sufficient for cane production without irrigation, but certain conditions of the natural setting give it individuality. Being located on the windward side of the Luquillo Mountains, which receive the heaviest rainfall of the island, the Canóvanas sugar producers have invested more capital in drainage projects than has any other north-coast company.¹ From steep mountain gorges and ravines numerous streams emerge to wend their way across a narrow coastal lowland. Torrential rains swell the streams and large areas of cane land are inundated aperiodically. Several

¹Manuel Vicente, "Drainage in Puerto Rico," Facts about Sugar, XVII (1932), 98.

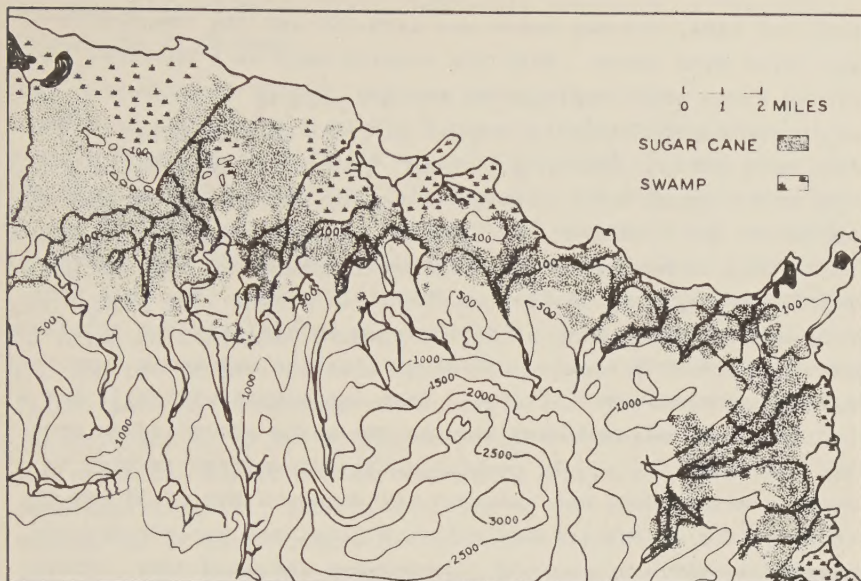


Fig. 2.--The cane belt of northeastern Puerto Rico in its general setting. The numbers on the contours represent feet. (Contour data from Progressive Military Map of the United States, Porto Rico Sheet 910 S 1 Fajardo. Cane belt plotted from vertical aerial photographs of Mapa Topográfico de Puerto Rico.)

rivers take sluggish courses through the swamps which occupy relatively large portions of the coastal lowland. Parts of these swamps have been reclaimed and have been added to the cane régime. Furthermore, much of the cane land requires continual care to keep the soil free from excess water.

The investigation began with a geographic survey of the district in 1932. The major aim of the field study was to discover areal differentiation in land utilization within a district which specializes in the production of cane sugar. The area tributary to Central Canóvanas was mapped in detail, combining field observations and data collected by workers in other disciplines. The work was facilitated greatly by the blueprint maps of the lands farmed by the Loiza Sugar Company, by the vertical aerial photographs taken the previous year by the Puerto Rican Division of Topographic Mapping, and by a detailed soil map made in 1929-30 by the United States Bureau of Soils in cooperation with the Insular Experiment Station. Maps of the eight plantations of the Loiza Sugar Company, which owns Central Canóvanas, provided an

excellent base, for the scale was 1:12,000 and the boundaries of each field were shown. With the company maps as a nucleus, adjoining areas were drafted from vertical aerial photographs. For this purpose, 258 pictures, each 9 1/8 by 7 1/8 inches in dimension, were used.¹ Taken at a height of 10,000 feet, each picture covers an area of 1,000 acres, scale 1:10,000. The base maps were carried to the field for verification and for the addition of field data. A composite map of land occupancy and site characteristics was prepared. Following the field survey, the data were analyzed for the purpose of discovering objectively the relations existing between patterns of land utilization and those representing natural conditions of site. From the complicated soil map a simplified map was made by grouping the soils according to profile characteristics. By combining the information carried by the generalized soil map and that portrayed on the field map of occupancy and site characteristics, a final map was constructed delineating soil-slope-drainage complexes and land uses. Planimeter measurements were made to determine the total extent of each unit. From these data the degree of coincidence between the areal distribution of the various land qualities and the areal distribution of the various land uses was calculated.

Much information was made available by various people in authoritative positions, without whose kind assistance the field study could not have been accomplished. A. R. Cochran, manager of Central Canóvanas and vice-president of the Loiza Sugar Company, was generous not only with data and counsel but with introductions which unlocked other sources of information. Manuel Vicente, drainage engineer of the Insular Experiment Station, who had formerly been in the employ of the Loiza Sugar Company; José C. Rosario, a professor in the University of Puerto Rico, who had made a sociological study of the hill people in the Canóvanas district; George Gerhart, assistant superintendent of the Insular Forest Service; F. E. Hartwell, head of the San Juan Station of the United States Weather Bureau; and F. A. Villamil, of the Soil Division of the Insular Experiment Station, all gave valuable assistance. The manuscript was prepared under the help-

¹Mapa Topográfico de Puerto Rico, Aerial Photographs: Series B-2-W,1-5; B-3-W,1-29; B-4-E,1-24; B-5-W,1-27; B-6-E,1-25; B-7-W, 1-25; B-8-E,1-23; B-9-W,1-25; B-10-E,1-25; B-10x-W,1-29; B-11-E,1-21, December 1930, January and February, 1931.

ful direction of R. S. Platt, associate professor of Geography, University of Chicago.

General Aspects of the District

The Canóvanas district supports a population averaging 443 per square mile (1930). This is approximately the same average density as that of the whole island. In a narrow strip of high-quality land stretching across the district from the foothills to the sea, densities run from 600 to more than 1,200 people per square mile (Fig. 3). The lowest density within the district is found in a few small civil divisions which lie near the coast and consist largely of sand beach and swamp. Even there the population exceeds 100 people per square mile. The southern part of the district is in the highlands and there densities of 200 to 400 prevail. Higher in the mountains, beyond the limits of the Canóvanas district, densities of 100 to 200 continue up to the boundaries of the Luquillo National Forest, which is closed to settlement. The population of the Canóvanas district is classed as rural, for the towns are small and four-fifths of all people gainfully employed in the district are engaged in agriculture. This large rural population is one of the factors contributing toward intensification of the cane industry.

The Canóvanas district occupies one of the broader segments of the cane belt which encircles the island, widening and narrowing in conformity with the configuration of the land. In the Canóvanas district the solid formation of cane attains a maximum width of four miles (Fig. 4). As the cane belt continues eastward it narrows to less than a mile, pinching out where spurs from the Luquillo Mountains radiate to the coast. To the west of the Canóvanas district the cane belt continues for some distance but it is interrupted by a citrus-fruit development near the port of San Juan.

The greater width of the cane belt in the Canóvanas district bears witness to the land building accomplished by the Río Grande de Loiza, one of the two major streams of the island. Joining the alluvium of the Río Grande de Loiza to the east are the bottom lands of its two major tributaries and of four small streams which take their sources in the rain-drenched heights of the Luquillo Mountains. The fertile alluvial lands of this series of rivers form the nucleus of the cane régime which focuses upon

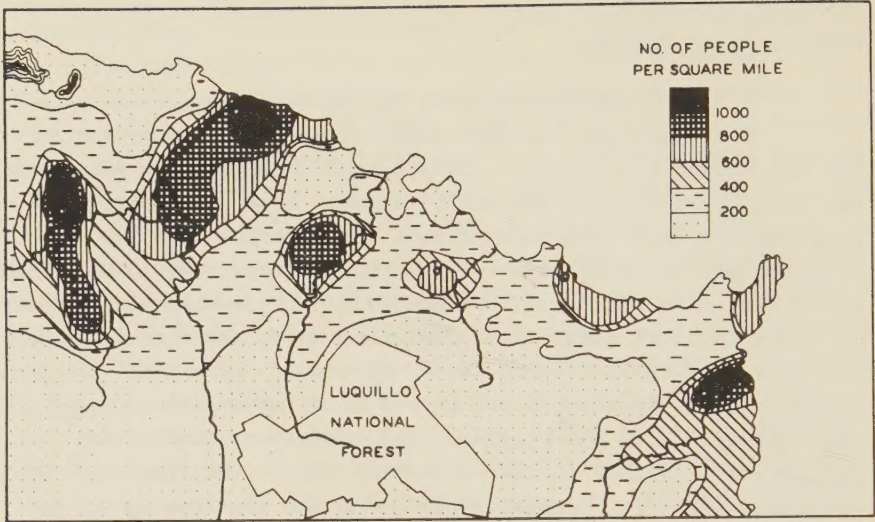


Fig. 3.--Population density of northeastern Puerto Rico, 1930. Scale, 1:15,000. (Population data from Outlying Territories and Possessions, Fifteenth Census of the United States: 1930, pp. 125-31. Barrio boundaries from map of Puerto Rico, Department of the Interior, Division of Public Lands. Area of barrios measured by planimeter.)

Central Canóvanas, standing on the east bank of the Río Grande de Loiza. Although the major part of the Canóvanas cane belt is associated with rivers, there is a considerable extension into the foothills which flank the mountains. In some sections smoothly rounded hills are completely covered with cane. The crop climbs in somewhat continuous formation to approximately the 500-foot contour. Even on to the lower mountain slopes cane ascends, but there the continuity of the belt is broken. Small fields cling to precipitous slopes here and there, great expanses of uncropped land intervening. From altitudes of 500 to 1,000 feet are the patchy outliers of the cane belt. Above 1,000 feet, little cane, if any, is planted (Fig. 2).

The Canóvanas district is relatively small, no larger than two mid-western townships in the United States, but it consists of contrasted areas which exhibit true geographic entity. Throughout the district the rainier phase of the Low-Latitude-Wet-and-Dry type of climate prevails (Figs. 5 and 6). In general the amount and distribution of rainfall are suitable for cane culture without irrigation. However, contrasts in soil, slope, and drain-

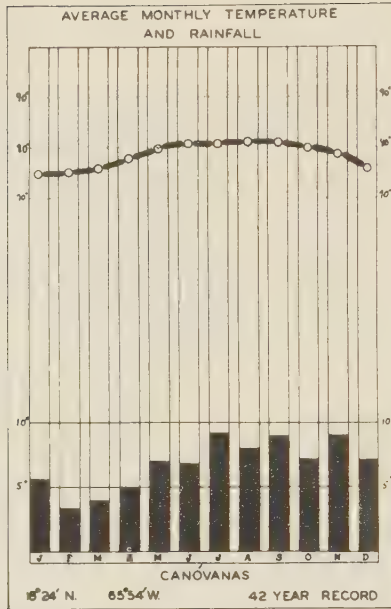


Fig. 5.--Average monthly temperature and rainfall of Canóvanas. The average annual precipitation is 79.4 inches. The probability of a dry February is 78 per cent, March 69 per cent, and April 66 per cent. (Data from Annual Summaries of Canóvanas in files of U. S. Weather Bureau, San Juan.)

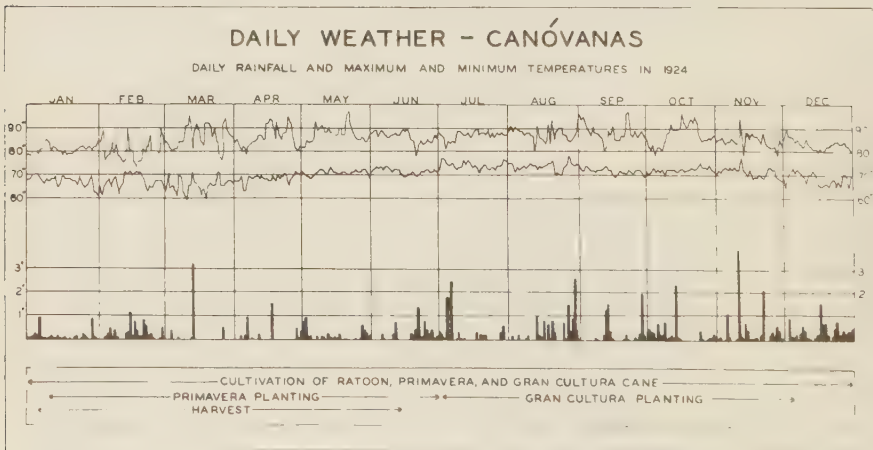


Fig. 6.--Daily rainfall and temperature and calendar of work in the cane fields. (Climatic data from Monthly Weather Reports of Canóvanas, files of U. S. Weather Bureau, San Juan.)

age are so marked that the efficiency of precipitation varies from place to place and the climatic risks of drought, hurricane, and excessive rain differ in intensity within short distances. Contrasts in soil, slope, and drainage show an orderly arrangement with reference to one another, since the effectiveness of drainage depends largely upon slope, and since both slope and drainage rank as major factors in the genesis of soils. The soil map displays a complicated pattern of a score or more of soil types, each type exposed repeatedly in small areas.¹ These types, delineated by soil scientists through the application of fine distinctions, fall into groups whose areal spread coincides with that of certain slope and drainage types. Thus, the district consists of areal units, each characterized by a particular soil-slope-drainage complex. Observation of the cultural landscape reveals the fact that the soil-slope-drainage boundaries differ in significance. Of particular geographic note are the boundaries of soil-slope-drainage complexes which coincide with one or more boundaries of cultural distributions. An area enclosed by such a coincidence of boundaries has marked individuality in natural qualities, and its natural characteristics have made an impress upon the cultural pattern. To such divisions, representing collaboration between man and nature, the term "land type" is applied in this study. Each major land type has been named from a locality where there is a relatively large exposure. Within each major land type there is considerable variation in minor elements, but for the purpose of this study only the more pronounced have been treated.

Five major land types have been identified in the Canóvanas district (Figs. 7 and 8). The larger cane-producing types are the San Isidro and Hacienda Grande, both of which occupy portions of the coastal lowland (Fig. 9). The San Isidro type is of rich alluvium, the stronghold of cane. The Hacienda Grande type represents the swamps, portions of which have soil of high enough fertility to warrant reclamation and introduction into the cane pattern. On the seaward edge of the district stretches the Loiza land type which is inhospitable to cane, but is the seat of a flourishing development of coconut groves and vegetable gardens.

¹A. T. Sweet and F. A. Villamil, Soils of Canóvanas District, 1931. Copy of manuscript map in files of the Loiza Sugar Company.

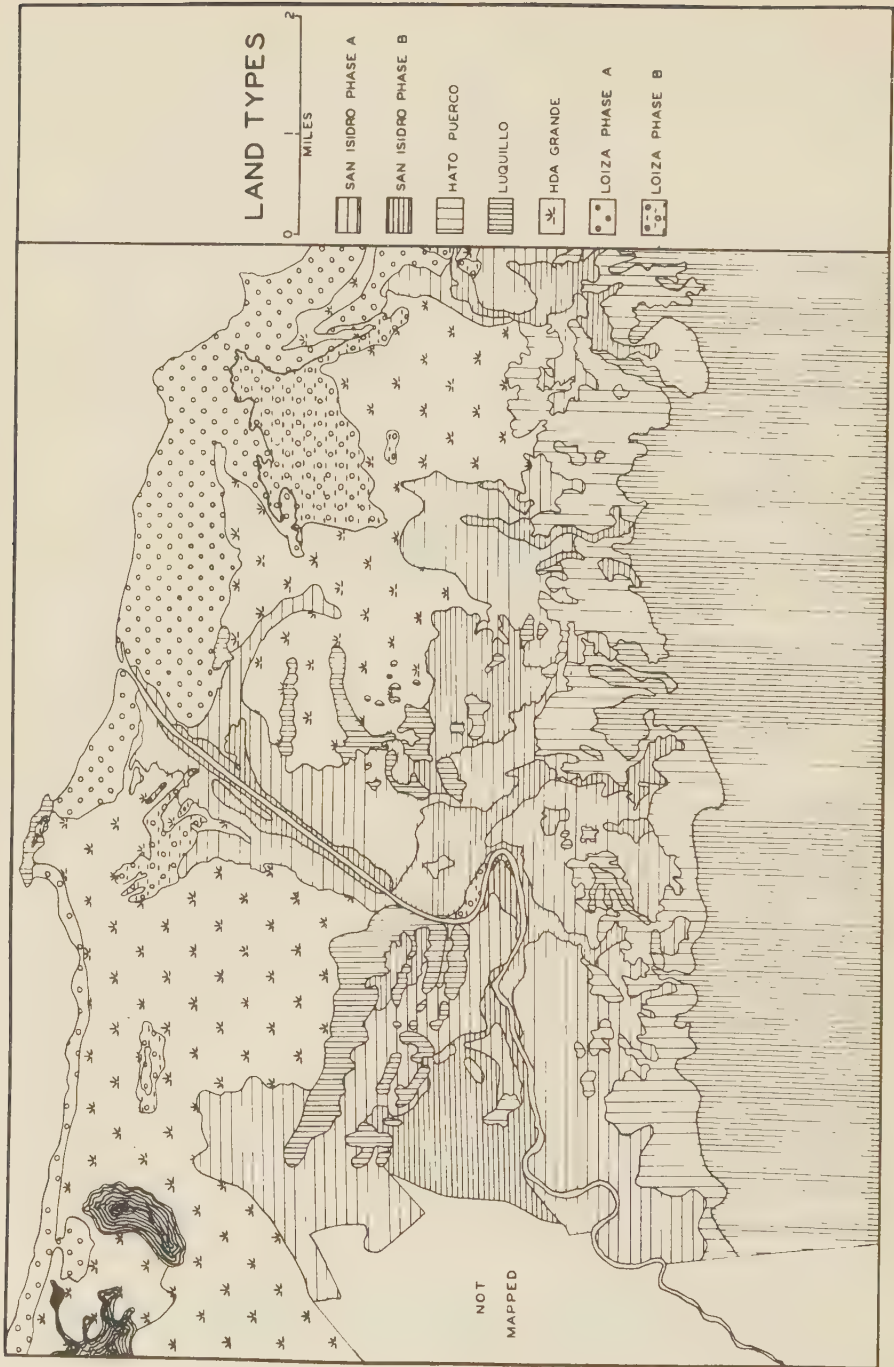


Fig. 7

Land Type	Cuerdas* (Acres)	Per Cent of the District	Key Characteristics
San Isidro	9,239	27.7	Recent alluvium Deep silt and clay loams Flattish to gently sloping Imperfect natural drainage
Hato Puerco	3,179	9.5	Shallow residual soils Rounded foothills Moderate to steep slopes Excessive drainage
Luquillo	8,703	26.1	Very shallow residual soils Steep mountain sides Excessive drainage
Hacienda Grande	8,307	24.9	Deep cumulose soils Sea-level swamps No natural drainage
Loiza	3,956	11.8	Beach sands and sandy loams Flattish to gently sloping High water table
Total ..	33,384	100.0	

*Cuerda is the unit of land measure used in Puerto Rico. It equals 0.9712 acre, as defined in the Register of Puerto Rico, 1926, p. 304.

Fig. 8.--Land types of the Canóvanas district

In the highlands lie the Hato Puerco and Luquillo types, the former presenting second-rate lands to cane growers, the latter affording little opportunity for profitable cultivation of any kind.

Such an array of soil, slope, and drainage presents problems to the agriculturalist. The modification of general practices to comply with diverse site characteristics has taxed the ingenuity of highly trained cane men. To provide adequate drainage for low-lying lands and to check excessive drainage on hill-sides have called for the skill of civil engineers. To accomplish transport of heavy loads on wet lands has entailed great expenditures for railroad construction. However, there are compensating advantages in utilizing such a diversity of land types in a one-crop economy. The range of land forms in the Canóvanas district is so great that susceptibility to damage by flood, hurricane, and drought varies in marked degree and a wide spread of losses is consequent. These three uncertain factors with which the cane

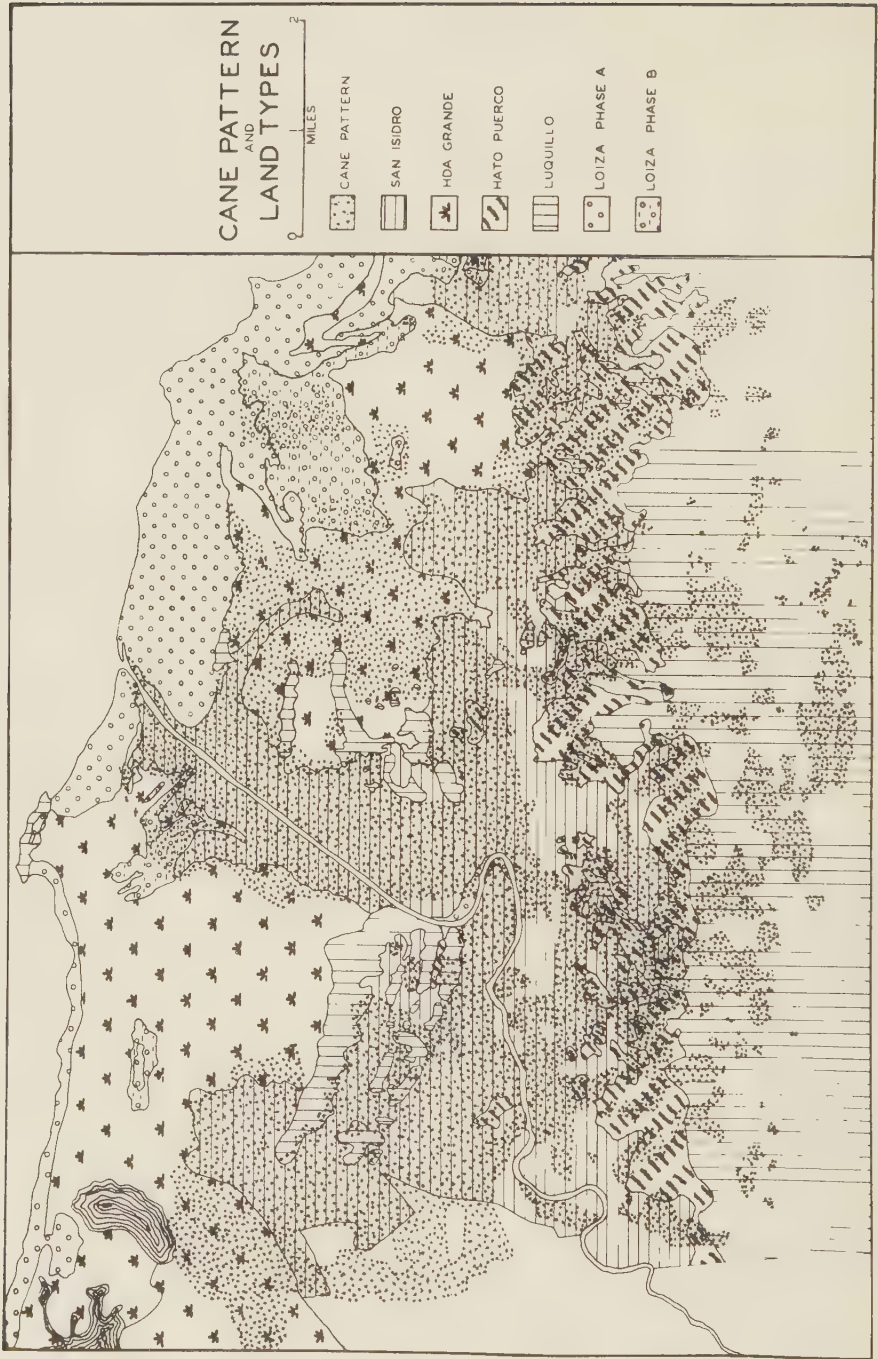


Fig. 9

grower has to gamble strike at different periods and may damage cane on one land type and pass by cane fields on another land type. Low-lying fields produce the big crop in drought years and are reduced in productivity in flood years. The hillside fields suffer in drought and hurricane years and thrive in the wetter years.

San Isidro Land Type, the Stronghold of Cane

General characteristics.--The significance of the San Isidro land type in the Canóvanas cane pattern is great in proportion to its areal extent. It makes up only a fourth of the district, but it accommodates half the acreage of cane milled in Central Canóvanas (Fig. 10). Its suitability to cane is demonstrated by large plantings, high yields, and the continuance of cane cropping through several centuries. It is well suited also to the organization of large plantations, and is proving highly satisfactory for the application of intensive methods of cultivation. Its disadvantages lie in the danger of inundation, imperfect drainage, difficulty of plowing, and hindrance to transportation.

Sugar cane has undisputed rights on this land type, for 75.6 per cent of the acreage was in cane in 1932 and an additional 13.9 per cent, then in grass, gave evidence of being occupied by cane in rotation with grass fallow (Fig. 11). A total of 89.5 per cent of the San Isidro type, therefore, can be classed as cane land. The rest, amounting to 10.5 per cent, lies in small patches among limestone monadnocks, on the borders of swamps, or on valley floors where danger of flooding is imminent. Such a high degree of coincidence in the areal distribution of a land type and in acreage of cane gives a measure of the suitability of the type for this crop.

The largest area of the San Isidro land type borders either side of the Rio Grande de Loiza and its major tributaries. Carrying detritus from a mountain basin whose southern edge lies within eight miles of the Caribbean coast, the stream has spread its load on the coastal lowland. The natural levees along its six-mile course over mud flats of its own building form a slightly elevated ridge where agriculture early gained a foothold. From the lands close to the river cane culture spread into imperfectly drained land behind the levees. On the west side of the river

Land Type	<u>Cuerdas</u> in Cane	Per Cent of Canó- vanas Cane Land
San Isidro.....	6,969	52.3
Hato Puerco.....	2,008	15.1
Luquillo.....	1,637	12.2
Hacienda Grande.....	2,354	17.7
Loiza.....	355	2.7
Total.....	13,323	100.0

Fig. 10.--Composition of the Canóvanas cane belt, 1932

Land Type	Area ^a	Cane	Grass Fallows	Perm't Pasture and Gardens	Coco- nuts	Man- grove Asso- ciation	Vil- lages	Total
San Isidro	acres ^b %	6,969 75.6	1,289 13.9	858 9.2	27 0.3	59 0.6	37 0.4	9,239 100
Hato Puerco	acres %	2,008 65.2	346 10.9	794 25.0			30 0.9	3,179 100
Luquillo	acres %	1,637 18.8	34 0.4	7,009 80.5			23 0.3	8,703 100
Hacienda Grande	acres %	2,354 28.3	60 0.6	432 5.2	32 0.4	5,439 65.5		8,307 100
Loiza	acres %	355 9.0	148 3.7	19 0.5	2,854 72.1	530 13.4	50 1.3	3,956 100
Total	acres %	13,323 39.9	1,867 5.6	9,112 27.3	2,913 8.7	6,028 18.1	140 0.4	33,384 100

^aAreas occupied by highways, trails, canals, scattered dwellings, and small gardens have not been differentiated, due to the fact that planimeter measurements were made upon the map after reduction to a scale of 1:40,550.

^bAcres is used as a translation of cuerdas.

Fig. 11.--Occupance of the various land types in the Canóvanas district in 1932.

the strip of alluvium is little more than a half mile wide (Fig.12). From the crest of the levee, about 800 feet from the river, the land slopes back gradually for a half mile into a sea-level swamp. On the east side of the river the exposure of alluvium is much

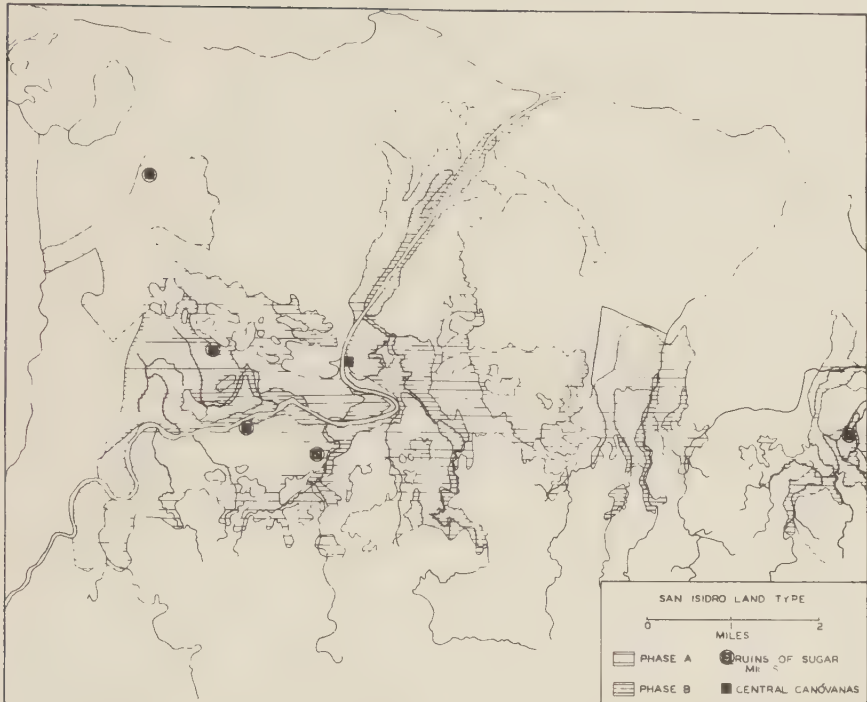


Fig. 12.--San Isidro land type. Phase A represents the more imperfectly drained lands, Phase B the lands on slightly higher ground from which the run-off is more rapid. The ruins of sugar mills in the Canóvanas district stand upon San Isidro lands.

larger than on the west side, probably due to the fact that contributions of several tributaries coalesce with the deposits of the master stream. Here is the plantation called San Isidro, from which the land type takes its name (Fig. 4). Smaller sections of the San Isidro type lie along the Gordian, Cambalache, Herrera, Rio Grande, and Espíritu Santo rivers, a series of small streams to the east.

Extensive uninterrupted areas of San Isidro land are suited admirably to the development of a system of plantations. The 700-acre block of alluvium northwest of the Rio Grande de Loiza and northeast of the limestone hills is the seat of Colonia¹ Virginia (Figs. 4 and 13). To the south of the hills is another large area enclosed by the big bend of the Rio Grande de Loiza, where Colonia Santa Barbara is located (Figs. 4 and 13). West of the hills lie 900 acres, which make up part of Colonia Machicote. East of the river the various blocks of San Isidro land are occupied by colonias San Isidro, Dolores, and Carmen, each more than a 1,000 acres in size. Six of the eight plantations operated by the Loiza Sugar Company are composed largely of San Isidro land.

Suitability of soils for cane culture.--The soils of the San Isidro land type are well adapted to cane provided care is taken to correct imperfect drainage conditions. The soils included in this land type are ten in number, heavy loams varying from silt loams to clay loams.² They are sticky when wet, but friable when partly dry, and easy to cultivate when moisture conditions are right. During long periods of rain they become sodden and all cultivation must cease. The surface loams vary in thickness from six inches to twenty-five inches. Underlying these surface loams are two to thirty inches of more compact loams. Beneath, lie layers of relatively stiff clay.³ In some places this clay horizon is so tight that it is practically impervious to drainage waters. The San Isidro soils over most of their extent give a neutral reaction, in smaller areas a slightly acid reaction. Each field is tested every four or five years and only a few

¹A colonia is a plantation composed of parcels of land under various ownerships but with one management.

²R. Wildermuth, Notes on Soils of Canóvanas. MS in files of the Insular Experiment Station, Río Piedras, Puerto Rico.

³Ibid.

tracts have shown a need for corrective application of lime. Sugar cane, intolerant of either salinity or acidity, finds in most of the San Isidro soils an almost ideal habitat.

The distribution of the ruins of five mills in the Canóvanas district testifies to the recognition given San Isidro land by earlier cane growers. Each of the ruins stands near the center of a relatively large exposure of the San Isidro land type (Fig. 12). These mills operated in days when the slow oxcart was the means of transporting cane. One by one they were dismantled when narrow-gauge railroads were built and when the introduction of large-scale machinery made it profitable to concentrate the processing of the cane of the Canóvanas district in one large modern central.

For centuries the San Isidro lands have produced cane. In 1581 three of the eleven sugar mills then on the island were operating in the Canóvanas district.¹ Of seven sugar mills on the island in 1646, one was at Canóvanas.² In 1776 Canóvanas ranked third among the districts of the island in sugar production.³ A mill, called La Punta, stood in 1880 on the identical site now occupied by Central Canóvanas.⁴ Part of the stone structure of that old mill stands as a section of the warehouse of the present central.

Agricultural procedure aims for high returns per acre and for maintenance of soil fertility. Intensive methods of cultivation are employed and fertilizer is applied for each crop. Yields of cane on the San Isidro lands are high, averaging 50 tons per acre in contrast to 32 tons for the district as a whole. In 1932, one field near the mill produced 92 tons. This record field has produced cane for more than three centuries. Fertilizer has been applied to San Isidro lands in recent decades, not because of diminishing yields, but to increase production and to grow cane continuously on the same land without grass fallowing.

¹Cayetano Coll y Toste, "La Propiedad Territorial en Puerto Rico. Su Desenvolvimiento Histórico, III La Caña de Azúcar," Boletín Histórico de Puerto Rico, I, 245.

²Ibid.

³Fray Íñigo, Abbad y Lasierra: Histórica, Geográfica, Civil y Natural de la Isla de San Juan Bautista de Puerto Rico. Nueva Edición (1866), p. 313.

⁴F. R. Hilera, "Sugar Production in Puerto Rico." A. B. Gilmore, Sugar Manual of Porto Rico, 1930-31, p. 7.

Fig. 13.--Cane fields on parts of colonias Virginia, Santa Barbara, San Isidro, and Hacienda Grande. The gran cultura crop is an eighteen month crop, planted from June to December, grows all the next year, and is harvested the following January to June. The primavera crop is a twelve month crop, planted from January to June and harvested during the following "crop," January to June. (Data on cane classification from the Loiza Sugar Company Crop Book, 1932.)

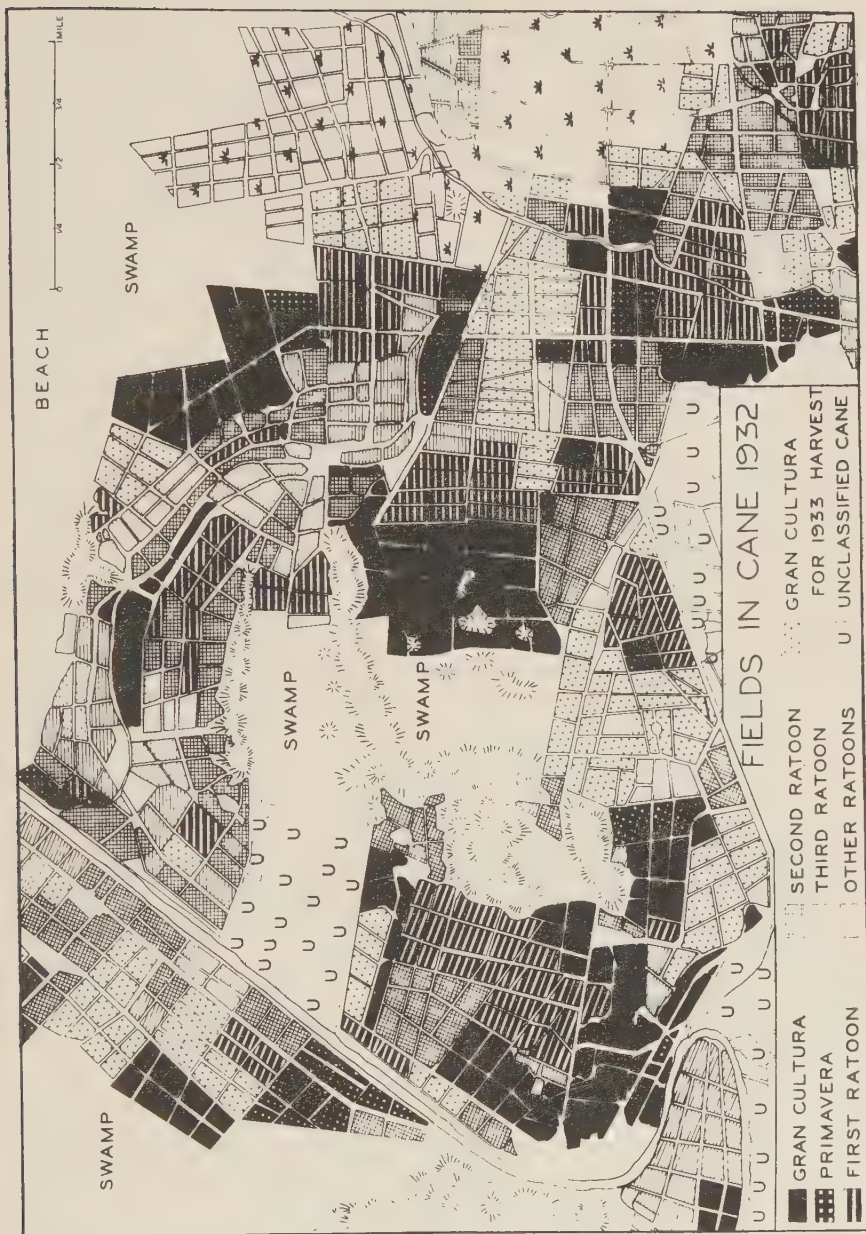


Fig. 13

Drainage problems.--The San Isidro land type is imperfectly drained, the degree of imperfection varying from place to place. Drainage problems arise not only from the low angle of slope but also from the impervious clay horizon which underlies the surface silt loams and clay loams. The more poorly drained lands make up seventy-three per cent of the area and require a close network of drainage ditches and specialized methods of planting and plowing. They lie behind the natural levees of the Río Grande de Loiza and on its flood plains above the upstream limit of the levees. Along the smaller streams are flood plains on which no natural levees have been built. This more poorly drained phase of the San Isidro land type has been designated phase A (Figs. 12 and 14). The remaining twenty-seven per cent, phase B, is slightly higher land from which the run-off is more rapid, on natural levees, on terraces, and on older alluvial deposits. Less attention needs to be given to the drainage of phase B and the pattern of ditches is less closely meshed than on phase A.

Phase		Cane	Grass Fallow	Perm't Pasture	Coco-nuts	Swamp	Villages	Total
A	acres	4,902	989	812	27	59	14	6,803
	%	72.1	14.5	11.9	0.4	0.9	0.2	100
B	acres	2,067	300	46	...	...	23	2,436
	%	84.9	12.3	1.9	...	...	0.9	100
Total	acres	6,969	1,289	858	27	59	37	9,239
	%	75.6	13.9	9.2	0.3	0.6	0.4	100

Fig. 14.--Occupance of phases A and B of the San Isidro land type, 1932.

Some of the lands of Colonia Virginia, on the west side of the lower course of the Río Grande de Loiza, have been drained by lateral ditches which empty into old transportation canals (Fig. 15). These canals were dug in the 1840's to connect the fertile lands of the Río Grande de Loiza with the chain of lagoons to the west, by way of which there was continuous navigation to San Juan, the largest settlement on the island.¹ The southernmost

¹Cayetano Coll y Toste, "Canal de Loiza a la Laguna de Piñones de la Gaceta Oficial," Bol. Histórico de Puerto Rico, II, 218.

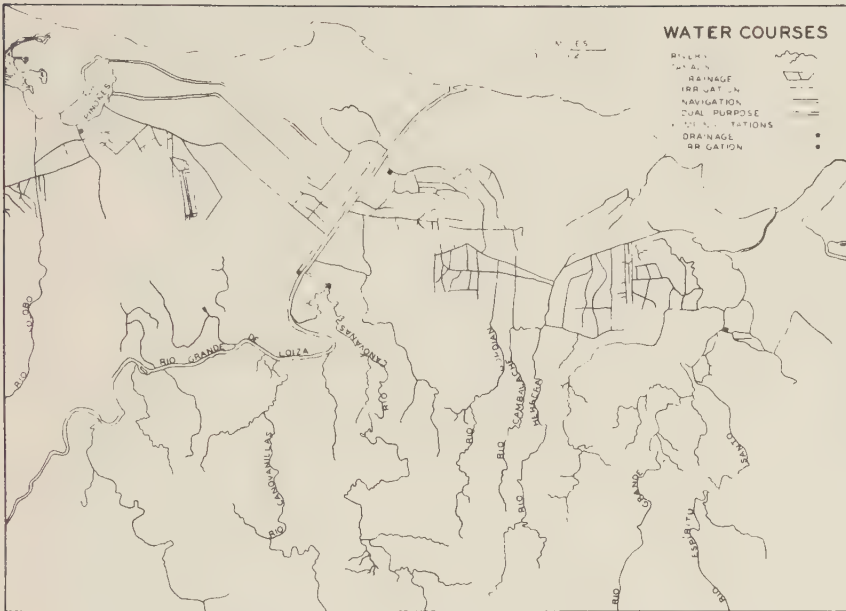


Fig. 15.--The water courses of the Canóvanas district. Most of the water courses are drainage ways. There are two short irrigation canals that are of recent origin. After the serious drought of 1930, they were constructed to supply water from the Río Grande de Loiza for new cane plantings and ratoons on half the acreage of colonias Virginia and San Isidro.

of the canals was originally constructed to enter the river. At high tide, water rose in the canal. In time of flood, river water backed into the canal and spread out upon the bordering lands behind the levee. When the cane grower wished to reclaim these lands, the navigation canal was blocked by a wooden and earthen dam, so that water from the river could no longer enter it. Drainage ditches were dug to open into this main canal and the surplus waters are carried off down slope into a swamp which lies some fifteen or twenty feet lower than the land along the levee.

On the east side of the river, a system of drainage ways into the swamp similar to that employed on the west side had to be abandoned when the swamp itself was to be drained. Therefore drainage waters had to be turned into the river (Fig. 15). The difficulty was to make the main canal deep enough to carry water from sea-level swamps out through the higher land of the levee and yet not admit river water at high tide into the canal system. This problem was met by the construction of a dam with sluice gates at the point where the main canal goes through the levee. There at the dam, a pumping station was erected. The neighboring San Isidro lands have benefited greatly by this drainage enterprise, although the project was undertaken primarily to drain part of the swamp.

Agricultural techniques.--The sticky character of the San Isidro soils and the sluggish drainage have required special field methods. On the better drained lands, phase B, the general practice of furrowing dominates. Furrows in which to plant pieces of cane are opened five feet apart. In the more critical areas a sub-soil plow is used which cuts down directly below the furrow. Even in the preparation of the ratoons,¹ the sub-soil plow has been found effective. Drainage ditches are opened every fifteen or twenty feet. On the more imperfectly drained lands, phase A, a special method of planting has been devised. It is called gran banco. Furrows are laid out seven to ten feet apart. By the use of spades the furrows are deepened into ditches a foot wide and eight to ten inches deep, the soil being thrown to the center of the bank. Upon the bank, shallow holes are opened in which pieces

¹The first crop cut after cane is planted is called plant cane, the succeeding crops which grow from the old roots are called ratoons. The general practice in Canóvanas is to cut two ratoon crops.

of seed cane are planted. More hand work is needed in this type of planting than in the furrow method, but it is essential on the wetter lands. Work on the drainage ditches continues through most of the year, in order to keep them clear of weeds.

To plow low-lying fields in wet weather is difficult, but all plowing cannot be postponed until the dry season. Certain fields are not harvested until May or early June, after the rainy season has begun. If the last ratoon crop is cut, then the field is due for plowing and replanting. To wait until dry weather would mean a loss of six months in the use of the land.

Various types of machinery have been tried in an effort to simplify the problem of plowing poorly drained land. The steam plow was used, but recently has been abandoned at Canóvanas in favor of light caterpillar tractors. They are proving fairly satisfactory, but occasionally trouble is encountered. Tractors with their plows, harrows, and furrow-makers have been mired. One case was reported of an outfit mired in September that had to be left until February before there was a period of dry weather long enough to enable workers to get it out.

A recent invention, the Gyrotiller, is being considered for use on Canóvanas lands. It performs the operations of plowing, harrowing, and furrow-making simultaneously. The heavy machine moves on stubble, leaving the furrowed land behind it. Thus it can work in wetter weather than a tractor and can accomplish in short order all preparations for seeding.

Danger of floods.--Most of the San Isidro lands are likely to be flooded. The Rio Grande having entrenched itself following recent uplift,¹ the banks are abrupt and the tenacious sub-surface clay holds a steep face. The amount of entrenchment, however, is not sufficient to keep the river from overflowing its banks during abnormally heavy rains. The river rises suddenly with heavy down-pours on the plains and in the mountains, and becomes bankful many times each year. Almost every year and occasionally several times in one year the flood stage is reached and bordering lands are inundated. To guard against damage, measures of protection have been provided. Sags in the natural levees have been filled. The top of the whole levee has been raised several feet along certain

¹H. A. Meyerhoff, The Geology of the Fajardo District, Porto Rico. N. Y. Academy of Sciences, Scientific Survey of Porto Rico and the Virgin Islands, Vol. II, Part 3, pp. 347-55.

critical stretches. At maximum flood stage, however, there are still places where water goes over the top, and for a few days hundreds of acres of cane fields look like an inland sea. Although floods may damage standing cane, there is compensation for future crops in the deposits of rich mud left by the receding waters.

Transportation of cane.--The nature of the soil and the drainage calls for special methods of transportation. The removal of an average of 50 tons of cane from each acre is a problem in itself. The harvest is staged for the comparatively dry season, but even then there are occasional copious showers. A torrential downpour on clay soils on a nearly level surface presents problems to the transport agencies. Two-wheeled carts, carrying heavy loads of cane, are likely to be mired in the slippery clay of the cart roads, deeply rutted by wheels and chopped full of holes by hoofs of oxen. Not only may the harvest be brought to a standstill, but there is danger that the large wheels, four-and-a-half feet in diameter, may cut down into cane roots and damage the ratoon crop. A close network of thirty-inch gauge railroads solves the problem not only on San Isidro lands but also on other lands of poor drainage (Fig. 16). The layout of the railroads is such that practically all cane fields on the San Isidro and Hacienda Grande land types are within a half mile of fixed track. From the fixed track, portable tracks are laid into the harvest fields. Small cars of two-and-a-half ton capacity are pulled on them by oxen. As the cutting front recedes, more sections of portable track are added. Central Canóvanas has a greater mileage of fixed track than any other central on the island, for there is more cane land gridironed with drainage ditches in the Canóvanas district than in the tributary area of any other Puerto Rican central.

Major uses of the San Isidro land.--In a relatively short time a selective process has eliminated various supply crops in favor of a single money crop. Food crops for local consumption have given way to cane which is processed into raw sugar for over-sea shipment. Sugar cane no longer has any strong competitor on the better lands. It is true that only three-fourths of the San Isidro lands were in cane in 1932 (Fig. 11). However, most of the remainder was occupied not by another money crop, but by grass. The circumstances under which it is considered practicable to use



Fig. 16

cane land for grass are three: (1) grass fallow to reduce the acreage in cane and diminish the cost of fertilizer when the price of sugar is low, (2) pasture to accommodate work animals, and (3) pasture and forage crops for dairy herds. The practice of grass fallowing to replace or reduce the application of fertilizer is an inheritance from the days of extensive cane culture and is more common on lands operated by independent farmers than on the company plantations. Fields from which three or four successive crops of cane have been cut are allowed to revert to grass to rest for a year or two, and incidentally to serve as pasture. On administration lands (lands on which cane is raised under company management) small plots are devoted to grass in order to space pastures conveniently for work animals. These plots are, in fact, night pastures from which the laborers obtain their quota of oxen for the day's work. The pastures contain five or ten acres and are scattered widely throughout the cane fields. The amount of forage in a given pasture is usually not sufficient for the number of animals placed there. A common practice, accordingly, is to bring cart loads of cane tops from the harvest fields to supplement the grass. From time to time, some oxen are driven for rest to permanent pasture on the margin of a swamp or on a hillside. From the permanent pastures new supplies of animals are driven to the night pastures. These small pastures enter into the cane program at intervals, and to replace them new pastures are set aside when old cane fields are plowed for new planting.

There is a small development of dairying on the San Isidro type by some farmers who combine cane culture with dairying and by other farmers who make use of San Isidro lands that are drained too poorly and flooded too frequently to be cropped. In either case, location along a hard-surfaced highway leading to San Juan is a conditioning factor. The capital provides a market to which milk is trucked each morning. There is only a small consumption of fresh milk in the rural areas, where refrigeration facilities are not available.

Hato Puerco Land Type, Second-rate Cane Lands

Status in the cane belt.--After the better sections of the coastal lowlands had been used for sugar cane, the foothills afforded second-choice sites to cane growers. Under the stimulus of expanding markets and the tariff walls of the United States,

Puerto Rican planters ventured upon these medium-quality lands with hopes of gaining a reasonable profit. The cattle industry, which had dominated the rougher lands during the earlier years of American occupation, gradually gave way to the cane industry. Today nearly two-thirds (63.2 per cent) of the surface of the foothills is covered with cane, and grass fallows occupy 11 per cent. The remainder still is held by permanent pasture (Fig. 11). Although the Hato Puerco type is largely given over to cane, it makes up only 15 per cent of the Canóvanas cane land (Fig. 11).

The planters on the Hato Puerco land type are not confronted by drainage and flood problems, but they face the menace of soil erosion. There is also the problem of transportation of cane on steep slopes over slippery clay roads. In contrast to the cane plantations of the San Isidro type, the Hato Puerco cane lands are in the hands of small independent farmers. Dwellings are scattered, each one on a separate holding (Fig. 17). Yields of cane are lower than the average for the whole district, and in times of drought or hurricane crop failure is likely.

Soil cover on the slopes.--South of the east-west trunk highway rise the foothills. They are small, and only a few are more than 100 feet in height. Though the slopes range from about ten degrees to thirty degrees in steepness, they are smoothly rounded and comparatively free from gullying, notwithstanding several decades of occupation by a crop which requires interrow cultivation. Winding among these knob-like hills, which have been carved out of soft shales and stratified calcareous tuffs, there are many streams, the filaments of a well-developed dendritic drainage system.

The soil mantle is twenty-seven inches thick at most. The top soil is silt loam, dark brown to nearly black in color; it varies from a fraction of an inch to fourteen inches in thickness. It overlies a shallow layer of yellowish clay which is relatively compact. Acid in reaction, it is only a fair soil for cane and heavy applications of lime are needed. It is difficult to cultivate, for it becomes heavy and refractory when wet and breaks into hard sharp clods when dry.

In most places, the cultivation of such steep slopes would be a destructive use of land. The hazard is particularly great in areas with rainfall of a torrential nature like that of the Canóvanas district. However, the character of the soil accounts in

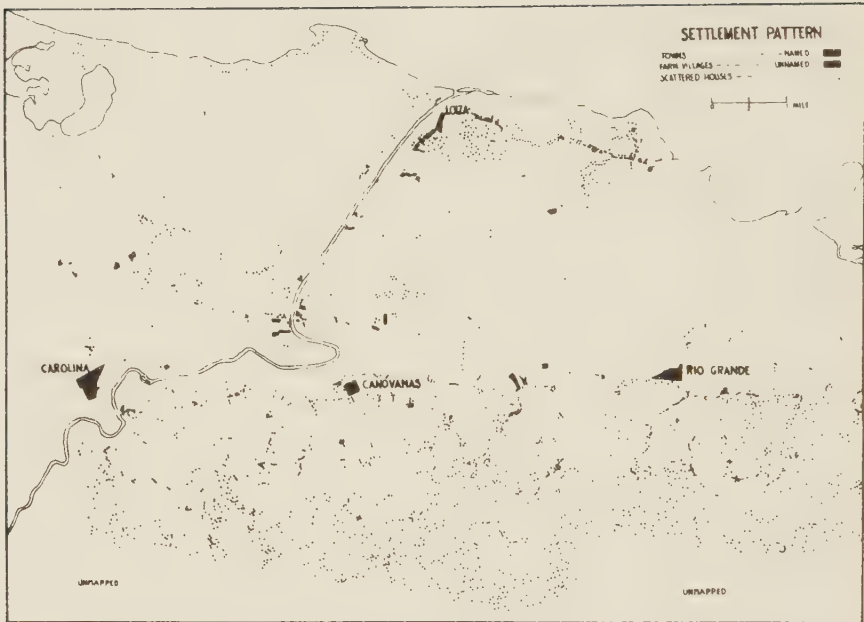


Fig. 17.--The settlement pattern in the Canóvanas district. The pattern displays two distinctive types: the nucleated farm-village mode in the lowlands where large plantations prevail, and the disseminated mode in the highlands where small farms are common. In the foothills there is somewhat of an alignment of houses along the roads. Farther south in the mountains, the road pattern is not reflected. It is a land of foot paths and pack trails, a spur leading to each house.

large measure for the fact that it is practicable to continue cultivation on the Hato Puerco hillsides. The soils are silt loams and clays which display powerful resistance to erosion. With great tenacity they cling to steep slopes. The truncated soil profiles indicate generous mass movement in the soils however, and a goodly amount of sheet wash induced by cultivation of the slopes.

Doubtless the character of the crop which is planted on these slopes tends to postpone the gully stage of soil erosion. Cane roots form a close mesh, which tightly binds the soil. The network of roots is not disturbed for some four or five years. When a field is renewed, only a week or two elapse from the time the roots are plowed up until new cane seed pieces begin to sprout. Thus a hillside field is without a protective vegetal cover for only a few weeks in four or five years.

Cultivation of the slopes.--Methods designed to diminish soil wastage have been applied to cane culture on the hillsides. Care is taken to follow contours when furrowing slopes. The furrows are opened three-and-a-half to four-and-a-half feet apart. The general practice is to plant more closely on hillsides than on lowlands, where five feet is the regulation interval between furrows. Drainage ditches are necessary on hillsides in order to conserve the contour furrows. The drainage ways are dug diagonally down slope, to carry the water off at as low a gradient as possible in order to lessen its erosive power.

The hillsides afford additional acreage for cane but possess few advantages for its cultivation. They are relatively expensive to operate, more hand work is necessary than on lowland fields, less work is done by oxen, and no machine work is practicable. The expense of harvest is several times as great as on low-lying land. The cane is transported entirely by ox cart, the slopes being too steep for a portable track to be used. Only one of the eight plantations operated by the Loiza Sugar Company, Colonia Calderón, is located partly on the Hato Puerco type. It is the smallest plantation and the one which returns least profit.

Hazards of drought and hurricane.--Although the hillside fields are free from floods and are well drained their owners may lose heavily in times of drought and hurricane. Over-drainage is not favorable to cane at any time, and is critical in periods of drought. There is little storage of water in the shallow soil on

the slopes and evaporation is rapid. When there is failure of rain for weeks at a time, great damage to the cane results. When winds of hurricane velocity blow, cane on exposed hillsides is ruined. Cane having shallow roots, is quickly uprooted.

Luquillo Land Type, the Poverty Zone for Cane

An area of "chronic crisis."--Having climbed the foothills with a fair degree of success, the cane belt flung outliers into the mountains. Only the more favored sites there were taken over by cane, however, and with little, if any, profit. A small part (12 per cent) of the Canóvanas cane belt is on this poor-quality land. The thin soils and steep slopes of the Luquillo type constitute a poverty zone for any kind of cultivation. The type represents "an area of chronic crisis" in the Canóvanas district. Many more subsistence farmers than cane farmers occupy the mountain slopes. The small amount of productive land has been divided and redivided among far too many people. Population densities of 100 to 300 per square mile on infertile soils and slopes, where soil wastage is making the land increasingly poor, mean an existence barely above the starvation level.

Behind the smoothly rounded foothills are the rugged highlands of massive tuffs. On their lower slopes, up to an altitude of about 1,000 feet, are small scattered cane fields. Only 18.8 per cent of the total area of this land type is given over to cane, a small part as compared to the 63.2 per cent cane cover of the foothills and the 75.6 per cent cane cover of the alluvial plains (Fig. 11). The mountains are closely and deeply dissected by many streams. Bold canyons, deep gorges, and steep-walled ravines are the result. Slopes of twenty degrees to thirty degrees are common and slopes of forty-five degrees are not rare. There is almost no level or gently rolling ground. The divides are so sharp that the natives call them cuchillos (knives).

The soils of heavy silt loam are thin, only an inch or two thick on the steeper slopes, no more than twelve inches on less steep slopes. Large rounded boulders are scattered over the surface in various sections. Some of the more easily accessible areas, with deeper soils and without boulders, are laid out in cane fields. The yields are low, only five to ten tons per acre. It is such cane fields which reduce the average yield for the Canóvanas district as a whole.

Outliers in the coastal lowlands.--Most of the Luquillo lands lie south of the main highway. However, there are numerous outliers in the coastal lowlands (Fig. 7). Out in the broad stretches of alluvial and lagoonal deposits stand many conical limestone hills. These rock "islands" in the monotonously flat expanses are erosion remnants, some of them 100 feet or more in height. On the west side of the Rio Grande de Loiza there is a comparatively large array of these hills, in an east-west alignment. They enclose flattish areas of uplands in which sink holes have developed. On the east side of the river is another group of hills, some of which stand in the swamps. Although these outliers differ greatly in origin from the mountains south of the foothill belt, their site characteristics of thin and rocky soils, steep slopes, and excessive drainage classify them with the mountain type. Relatively small areas are in cane; larger areas are in grass, with scattered scrubby bushes and here and there a tree stunted by frequent trimmings of the charcoal maker. There are a few slopes too steep for trails. High on the hills, out of reach of the wood gatherer, are patches of trees, bushes, vines, and ferns.

Cultivation of mountain slopes.--Mountain sides as steep as thirty degrees or even forty-five degrees do not deter the cane planter. He works on such slopes with much difficulty and gets poor returns for his labor, but so great is the urge to raise the crop for which he has an assured market that all that is necessary is location within sight of the smokestacks of a sugar mill.

On slopes of thirty degrees to forty-five degrees, which are considered too steep for contour furrowing, the hole method of planting is used. The seed bed is prepared with a spade; no use is made of a plow. Holes are dug and cane pieces planted in them. The common method of applying fertilizer is to open a hole up slope from the cane stool and bury the fertilizer. Seepage waters carry the plant nutrients to the cane roots and losses from sheet wash are minimized.

In years of high prices, some profit is obtained from steeply sloping fields, but in years of low prices many such fields are operated at a loss. Some fields never pay, even in years of high prices, but planters keep cane on them through force of habit.

Occupance by subsistence farms.--Land not occupied by cane

(80.5 per cent) in the Luquillo land type is given over to the gardens and pastures of subsistence farmers, the jíbaros. Gardening is of the primitive, migratory type. Tilled plots are left fallow for a few years between two cultivations; consequently there are shifts from plot to plot, but within a given area. The garden patches are very small, a fraction of an acre; on a farm of ten to twenty acres there may be several scattered gardens, each planted to one crop. Most of the jíbaros have no implements other than a machete, so tillage is rudimentary.

The common plants in the garden plots are sweet potatoes, beans, corn, yuca (Manihot Manihot), and yautía (Xanthosoma atrovirens and X. sagittaeifolium), plants which look like elephant-eared canna and bear large edible starch tubers. Patches of bananas are planted in sheltered places, deep in a ravine or on the lee slope of a hill, where there is protection against the steady wind from the northeast. There are scattered plots of tobacco which is grown during the cooler months. The amount of tobacco raised is so small, however, that no curing sheds have been built in the Canóvanas district. The sheaves of tobacco are hung from the ceilings of porches or even inside the houses.

The remainder of the land is in pasture, but there are relatively few animals. One farmer may have a goat, another a cow, a third a pig or two or a few chickens. Many jíbaros have no livestock. Pasturage is poor on the exposed, sun-burned slopes. In shady, moist places in ravines the grass is tall but coarse. There are many scrubby bushes, some of which, for example the gandul (cajan cajan), a bean, provide food. Scattered over the slopes are palms, breadfruit, and trees of various other kinds. Palms and breadfruit are common, for the charcoal maker does not find the palm suitable for his use and he does not injure the breadfruit tree, because it is greatly to be desired for its prolific crop of nutritious fruit. The jobo (Spondias Mobin) and pomorrosa (Jambos Jambos) are particularly in favor with the charcoal maker. Many of these trees are cut as soon as they attain suitable size, two or three inches in diameter, and others are trimmed of their branches at intervals.

To supplement a meager living, some subsistence farmers work in the cane fields during harvest, some pick berries on coffee fincas, which lie higher in the mountains above the 1,000-foot contour. The two harvests do not compete for labor, since the

coffee ripens from September to December, and the cane harvest does not open until January. Nevertheless, few of the mountain people work in both harvests. They must walk over steep, rough, mountain trails, crossing streams on stepping stones. Naturally, they choose to work in the harvest fields nearest their homes.

Hacienda Grande, the Frontier of Cane Occupance

Recent reclamation of swamp areas.--The Hacienda Grande land type is an area of vigorous economic development. It is a frontier area into which cane has advanced within the last decade. Upon its virgin soils are produced the largest cane yields in the Canóvanas district, and with the smallest amounts of fertilizer. The Hacienda Grande land type claims the mangrove swamps, which occupy nearly as large a part of the coastal lowland as does the rich San Isidro land type. For centuries the swamps supported a few people, engaged in the exploitation of wood resources. In recent years about a fourth of the swamps has been drained and transformed into the seat of a highly-intensive commercial agriculture supporting several hundred people per square mile.

The most recent additions made to cane acreage in the Canóvanas district were those of 1927. In that year the drainage of about 2,400 acres of tidal swamp was completed. Work was started on 1,250 acres more of swamp land, but was discontinued when the period of low sugar prices had persisted long enough to indicate that the expense was inadvisable.

One-fourth of the Canóvanas district originally was swamp land (Fig. 11). Behind the barrier beaches and the sand dunes lay large lagoons which served as catchment basins for the fluvial materials derived from hills and mountains. Through breaks in the dune ridge, sea water poured into the lagoons again and again. The salt-loving mangrove and its associates took possession of these partly filled lagoons and black muck and peaty material accumulated to great depths. The organic or cumulose soil of the swamps is rich and pulverizes easily when dry. The problem is how to drain these swamps which lie only a foot or two above mean sea level and a little below it during spring tide. Not only is it a matter of lowering the water table two-and-a-half to three feet, but also that of preventing the incoming tide from backing river water on to these lands. The flood hazard also must be reckoned with on certain stretches.

Drainage works.--The reclaimed swamp lands in the Canóvanas district are in three separate projects. The largest one, of 1,400 acres, is on the plantation called Hacienda Grande, which lies east of the Rio Grande de Loiza. The second largest unit is on Colonia Machicote, south of Laguna Piñones, with 450 acres of swamp drained, and 900 acres of bordering San Isidro land benefited. The third project is small, only 100 acres, and is north of the town of Rio Grande on the Rio Espíritu Santo (Fig. 15).

To remove surface waters, canal systems were dug and pumping stations erected (Fig. 15). The Hacienda Grande plantation is served by two miles of main canal, 30 feet by 6 feet in cross section, which opens into the Rio Grande de Loiza. Into the main canal empty thirty-five miles of lateral ditches of various sizes. When the project was started, digging by hand was the process of canal construction. The problem of deepening the main canal, however, grew to such dimensions that shortly it was found necessary to purchase a P and H half-yard drag line, a heavy gasoline-operated machine, for all work involving much soil excavation. The difficulty of using a machine of heavy tonnage on the soft, unconsolidated ooze of the swamps was overcome by using mats on which the machine moves and stands. The mats are made of timbers strung together on a cable, with suitable wooden blocks as separators between each set of logs. The machine itself is utilized in placing the mats and it carries them forward when advancing.

To move water in canals near sea level necessitated installation of pumping stations. The one which serves Hacienda Grande is on the main canal at the point where it enters the higher land of the natural levee, about a quarter of a mile from the bank of the Rio Grande de Loiza (Fig. 15). The pumping station is equipped with two electrically driven screw pumps, each having a capacity of 15,000 gallons per minute. They are supplied with submerged suctions and discharges in order to empty water through the concrete dam which was constructed across the main canal at this place. A power line connects the pumping station with the central's power house. Thus, the pumps are operated during the crop season on power which is generated by the use of bagasse, a by-product of the factory. During the "dead season," electricity is obtained from the Puerto Rico Light and Power Company. There is a disadvantage in the line method of obtaining power, however, in time of hurricane winds. In several instances the

wind has laid the power line low at the very time when high floods covered large areas which the pumps serve. Valuable time is consumed in repairing the wires before the pumps can be worked again. In the Machicote project, which lies about four miles northwest of the factory, the pumping station is equipped with a 6,000 gallon per minute centrifugal pump driven by a semi-Diesel engine, which is much easier to condition after a flood. Fuel oil is brought in by railroad and the station has been put into operation in twenty hours after the pump house was under water. The Rio Grande project is also equipped with a semi-Diesel engine.

Works are required not only to remove rain and seepage waters, but also to prevent river water from backing upon these low lands. With the incoming tide, mean range 1 to 1.1 feet, spring range 1.3 to 2.0 feet, the surface of the rivers rises several feet and water from them backs into the canals and tributary streams. To protect the reclaimed land against tidal inflow, dams and gates were needed. In the Hacienda Grande project, a concrete dam was built across the main canal where it enters the levee. The canal behind the dam has been widened to form a storage pond from which the pumps empty water. In the dam are three 5-foot by 5-foot sluice gates and one 16-foot by 4-foot gate provided for a 10-foot head. The gates are operated by hand. When the tide comes in, the gates are closed and the pumps started. When the tide goes out, the gates are opened and the pumps stopped. The gates are usually opened and closed twice a day. There is some variation in the schedule, however, contingent upon the distribution and intensity of the rainfall. In the small project near Rio Grande, there is a concrete dam with an automatic gate which opens and closes with the tides. Some trouble has been encountered through the clogging of this gate with debris washed from the fields. It requires considerable attention to keep the apparatus in proper condition.

The drained areas have been protected in low places by artificial levees in an endeavor to divert flood waters which are likely to pour in to the swamp lands when the rivers overflow their banks. Embankments ten to twelve feet high and thirty feet wide were built from materials obtained near by. The material is subject to excessive shrinkage and subsidence, and careful allowances were necessary in order to obtain a permanent levee of the prescribed size. For example, material for a dike 10 feet high and

30 feet wide required the excavation of a ditch 15 feet deep and 45 feet wide. Bermuda grass (Capriola Dactylon) was planted over the levees to hold them against the erosive power of torrential rains. Burrowing animals are a menace and must be fought continually. In several places limestone hills help to protect the low places from floods and in one place a short levee was built to bridge the gap between two hills.

Special methods of cane culture.--Planting methods are adjusted to drainage conditions. The gran banco system used on the more poorly drained San Isidro lands is the general one for the Hacienda Grande lands. Considerable hand work is needed on the ditches which gridiron the fields. If ditches slump in or become overgrown with weeds, cane suffers. In these drainage projects the cost of drainage per acre runs as high as the cost of irrigation on the south side of the island. If it were not for the high yields per acre due to the fertility of the soil, it would not be a paying proposition.

Soil characteristics and cane yields.--The high nitrogenous content of the swamp soils causes luxuriant growth of cane. Production of a hundred tons per acre without the use of any fertilizer is common. However, the sucrose content is low, the hundred tons of cane producing only seven tons of sugar, instead of the usual ten to thirteen tons. The carbohydrate-nitrogenous relation is such that vegetative growth goes on to the impairment of storage of sugar. This defect gradually disappears as soils are under cultivation year after year and their nitrogen content diminishes. By 1932 an increase in sucrose content of cane had been noticed in some fields.

Though these virgin soils have little need for fertilizer, there are circumstances under which one application is made for each crop. Certain areas in greater danger of flood than others, receive an application shortly after the new crop has had its first weeding. This is done in order to stimulate growth, so that the cane may attain sufficient height to recover in case of flood.

Utilization of undrained areas.--The undrained swamp still holds 18.5 per cent of the Canóvanas district. Only those tracts with better soils and position have been drained. The swamp to the west of the Rio Grande de Loiza has a composition different from that to the east of the river, which fact had a bearing upon the selection of the eastern swamp for earlier reclamation. In

the western swamp the cumulose soils exist for only a few feet down to a hard sub-stratum; in the eastern swamp there is no change in soil texture or composition to depths of at least fifteen feet.

The undrained swamps are waste areas as far as agriculture is concerned, but they contribute to the maintenance of some of the population. People who live on the sandy beaches combine wood gathering in the swamps with coconut culture. Large quantities of mangrove are cut as firewood for the bakery in the town of Canóvanas, and for making charcoal, the domestic fuel. Active cutting has not exhausted the supply of mangrove, for it is a rapid grower and in five to six years a cut-over area has enough new growth for the next crop to be removed. Other resources which attract workers into the swamps are large mangrove and ucar (Bucida Buceras) trunks which lie buried in the mud. The logs are large enough to be used for railway ties and for fence posts. The mangroves which are growing in the swamps at the present time attain a diameter of only a few inches before they are cut. The large mangrove logs that are buried reveal growth which took place before charcoal makers had penetrated the swamp. Ucar logs which are found buried in the muds with the mangroves are somewhat puzzling, for the ucar is not a species growing in the swamps today. It probably is a relic of growth at a time when the land was considerably higher than at present. The buried woods have been preserved in the quiet saline waters of the swamp and are well suited for use as railway ties or fence posts. The wood is so hard that holes must be bored with an augur for the spikes which are to hold railroad rails in place. Durability is an especially desirable attribute for railway ties in a land where high temperatures, high humidity, heavy rainfall, and poor drainage cause most wood to deteriorate quickly. Furthermore, there is the wood-consuming termite to consider. The mangrove and ucar are free from its attacks, since, for some reason or other, neither wood is acceptable to the termite's taste.

Transportation of wood through the swamps continues as in days of old on the canals constructed in the 1840's. In flat-bottomed boats, loads are poled along the shallow canals into Laguna Piñones, which is only two or three feet deep. There are connections from lagoon to lagoon, so that it is possible to pole from the swamps west of the Loiza River all the way to a shallow arm of the bay of San Juan. Over this route sacks of charcoal and bags of coconuts go to the city.

Loiza Land Type, Inhospitable Ground for Cane

Insignificance in the cane belt.--The Loiza land type attracts few cane growers, even though it is an area with a high percentage of arable land. Composed of beach sands, it is occupied by coconut groves interlaced with vegetable gardens. Only 2.7 per cent of the Canóvanas cane acreage extends on the Loiza land type. Rimming the coast are wide sandy beaches, phase A, protected from the full force of the waves by a number of barrier beaches and a reef. There are only 75 acres planted to cane in contrast to 2,781 acres in coconut palms (Fig. 18). Between the beach and the swamps there is a small transition zone of sandy loam, phase B, upon which cane growers have ventured but have profited little.

Phase		Cane	Grass Fallows	Perm't Pasture	Coconuts and Gardens	Swamp	Villages	Total
A	acres	75	34	5	2,781	46	41	2,892
	%	2.5	1.1	0.2	93.3	1.5	1.4	100
B	acres	280	114	14	73	484	9	974
	%	28.8	11.7	1.4	7.5	49.7	0.9	100
Total	acres	355	148	19	2,854	530	50	3,956
	%	9.0	3.7	0.5	72.1	13.4	1.3	100

Fig. 18.--Occupance of the Loiza land type

Along the coast is a narrow littoral of ten to twenty feet of bare sand where wind, wave, and tide prevent vegetation from gaining a foothold. To the west of the Rio Grande de Loiza, this littoral is backed by a dune ridge, ten to fifteen feet in height, stabilized by creeping vegetation and bushes. Behind the dunes the sands are dotted with coconut palms. To the east of the river, beach sands attain a width of a mile. There is no dune ridge there and coconut groves reach to the inner edge of the littoral. Inland, the beach is bordered in some stretches by mangrove swamps and in others by a transition zone of sandy loams. Less than a third of the sandy loams has been planted to cane, making an addition to the cane belt of only 280 acres. In some of these cane fields the saline content of the soil is too high for vigorous growth of cane. It has been found that the variety of cane utilized

on the silt loams and clays is not satisfactory on sandy soils, and another variety has been substituted with fair results.

Suitability for coconuts versus sugar cane.--The Loiza land type is occupied largely by the coconut palm, a non-competitor of sugar cane (Fig. 18). The two plants differ so widely in their physiological make-up that they thrive in very different habitats. Three environmental conditions are inhospitable to cane, but are tolerated by the coconut palm: (1) persistent winds of high velocity, (2) brackish underground water, and (3) soil of low fertility.

The coconut palm thrives in a wind-swept habitat. Its tough elastic trunk sways with the wind. A straight, up-standing coconut palm is rare. When winds reach hurricane velocity, some of the palms are likely to be uprooted, but the percentage is small. In the hurricane of September 26-27, 1932, about ten per cent of the Canóvanas palms were laid low. The crop of nuts, however, was a total loss, for all the fruits, flowers, and buds were blown from the trees that remained standing.

The coconut palm is well equipped to stand more light and wind than most plants can endure. As a matter of fact, its leaves are not merely tolerant of intense light and strong wind, but require both in order to function to best advantage.¹ The root structure is such that it can endure saltiness and dryness which would kill most other plants.² The fertility of the Loiza sand is so low that wide spacing of the trees is the general practice. On an acre only forty-eight palms are planted, the trees being spaced thirty feet from one another in rows thirty feet apart.

Relation of coconut groves to cane lands. The coconut fringe supports hundreds of families, some of which send workers to the cane fields. The most densely populated area in the Canóvanas district is the coconut-garden section around the village of Loiza (1,200 people per square mile). Many of these people are practically subsistence farmers, consuming the coconut meat from their palms and growing sweet potatoes, beans, and other vegetables in small plots among the trees. They add to their food supply by raising a pig or two on coconut meat and by catching land crabs at night with the aid of torches and small wooden traps. To ob-

¹E. B. Copeland, "On the Water Relations of the Coconut Palm," Philippine Journal of Science, I, 44.

²Ibid.

tain rice and a few other necessities, they sell some coconuts and occasionally a pig. Several small commercial enterprises exist, where tomatoes and cucumbers are raised for shipment to the continent for the mid-winter market. Some people add to their income by going into the mangrove swamps to work. Others labor in the cane fields.

The inhabitants of the coconut groves feel free to undertake work in the cane fields whenever they can obtain it, since the labor requirement in the coconut industry is neither heavy nor urgent. There is no periodicity in the fruiting of the coconut and consequently no seasonality in harvest or in cultivation practices. On a palm at any time there are waxy ivory-colored flowers, tiny green coconuts, and larger ones of all sizes to the full grown nut. The general practice is to harvest once a month or once in two months. The nuts are gathered on a dry day, for in wet weather the trunk is too slippery to climb. The coconuts are collected in heaps and left for a short time before husking. They are sacked and sent to San Juan by truck or canal boat. All the coconuts are sold fresh, some on the island and some in Continental United States.

Prospects of the Sugar Industry in the District

The sugar industry is entrenched deeply in the economic structure of the Canóvanas district. For more than three centuries the suitability of its climate and soils for growing cane has been recognized. High temperatures the year around, abundant rains for eight months and a comparatively dry season for four months in the cooler part of the year are ideal for the growth of sugar cane. An expanse of coastal lowland deeply covered with fertile silt and clay loams presents site characteristics conducive to abundant yields. Then, too, there is a sufficiently large and compact area of excellent land to warrant the construction of a modern central. Added to these advantages for production is an equally important marketing factor--location near a middle-latitude country with a huge sugar consumption and a great deficiency in sugar production.

The cane pattern of the district has expanded to an extent that probably represents the maximum for profitable production. Cane has displaced other crops on high-quality land until it now dominates practically all the better land. It occupies about two-thirds of the area classed as second-rate quality, taking the better

land in this class. In an effort to add to the acreage of cane, some planters ventured upon poor-quality land and have remained there even though returns are meager. Recently, a profitable addition has been made to the cane area by the installation of drainage works to reclaim several thousand acres of fertile swamp land. Even so, cane occupies less than half the total area of the Canóvanas district, for its expansion has been blocked by the unsuitability of certain land types. Cane gives way to mangroves in saline swamps, to coconut palms on sandy beaches, to pastures and primitive gardens on steep slopes with inferior soils.

The present methods of cane production are highly efficient, and the yield obtained probably is as great as can be secured profitably under existing conditions. Areal differentiation of cultural practices within the cane pattern is marked. Methods of plowing, planting, applying fertilizer, preparing the ratoons, draining, harvesting, and transport have been modified to suit specific site characteristics. Adjustment has been made not only to soil-slope-drainage complexes, but to the climatic and biological environments as well. Various field procedures have been arranged to synchronize with the rhythm in rain. The improvement of varieties of cane has caused a veritable revolution in the industry. The development of special methods for the control of different insect pests and plant diseases has brought notable results. In the line of soil treatment, however, much remains to be done. Steps have been taken to remedy unduly high acidity or alkalinity, but there still is much to learn about the reaction of cane to soil differences. At present, the same fertilizer compound is used on all soils.

The major problems now confronting the sugar industry in the Canóvanas district are matters of international scope and not those inherent in the district itself. They do not belong to the production phase of the industry, but rather to the marketing phase. The Canóvanas sugar industry was prospering and advancing rapidly toward climax production when a program of marketing control was set up according to the provisions of the Jones-Costigan Act passed by the United States Congress on May 8, 1934. The tonnage of Puerto Rican sugar admitted into Continental United States was restricted. A share of the quota was allotted to each central, and Central Canóvanas faced the problem of reducing its output.

Under the changed conditions, several courses of action

were open: (1) the central might seek new uses for cane; (2) the planters might reduce the cane acreage by substituting other crops; or (3) they might decrease the tonnage of cane by reducing the intensity of cultivation. The third measure was the one adopted because it could be put into operation quickly. It involved no experimentation with new crops, and no additional investment of capital for a new factory set-up, as would be the case if products other than sugar and molasses were to be manufactured. It simply was a matter of reverting to methods which had been in use a decade ago. Consequently, in the summer of 1934 a reduction in the intensity of cultivation was ordered. This was accomplished by continuing the ratooning of some fields beyond the usual second or third cutting and by returning to the practice of grass fallowing instead of using large quantities of fertilizer. This temporary solution of the problem, however, is disadvantageous from the point of view of the large number of laborers dependent upon field work for a living. Therefore, it is only a short-time, emergency measure. The uncertainty of future quotas makes planning difficult.

Experimentation with new uses of cane may make it possible to resume production at the level of 1932 even though a program of marketing control be continued. Various uses for cane besides the manufacture of sugar already are known. The practicality of such uses, however, is hypothetical. From the technological standpoint it is possible to produce rum and other alcoholic beverages, alcohol for motor fuel and industrial uses, and dry ice from cane juice, and to manufacture cellophane, rayon, and other cellulose products from bagasse.

Another possible method of restricting sugar production in the Canóvanas district would transfer some of the land to the culture of other crops. A marked shift in cropping is not expected in the immediate future, for the heavy investment of capital in mill and railways serves as a block to any radical change in crops. Minor changes may take place on the hillsides, if any crop more profitable than cane can be found. Formerly, the hillsides were the seat of a cattle industry, which furnished draft animals for the sugar plantations. A return to that form of land use is improbable, for it is incapable of supporting the dense population which now resides on the rough land. To the west of the Canóvanas district the citrus fruit industry occupies many

patches of rolling land. Whether this industry will extend its bounds eastward into the Canóvanas hills remains to be seen. Hurricanes constitute a greater hazard for citrus culture than for cane culture, since a long-term crop is involved.

Rotation of crops might result in a diminished cane acreage if this practice should be adopted. In this case, food-supply crops for the dense population of Puerto Rico probably would be included in the crop combination. Rice and beans, staple foods of the laboring class, might be raised as rotation crops instead of being brought from oversea regions as at present. Densely-populated Java has demonstrated the feasibility of maintaining high yields per acre by rotating cane with food-supply crops. The adoption of some modification of the Javanese system might give the Canóvanas district a more flexible economy.

In the Canóvanas district the sugar industry flourishes under favorable natural conditions and fortunate commercial circumstances. The Canóvanas area, like other Puerto Rican sugar districts, has definite advantages over other sugar-producing regions operating within the same tariff wall. Sugar-beet culture is handicapped by a large labor requirement and most of the American sugar-beet districts experience a perennial labor shortage. Sugar-cane culture in Louisiana, an adventitious tropical industry in a sub-tropical environment, depends upon a favorable tariff structure. As compared with the Hawaiian Islands and Philippine Islands, the other tropical producers under the American tariff, Puerto Rico has the advantage of a shorter shipping distance to Continental United States. Other West Indian sugar districts have the same advantage of proximity to continental markets, but they lie outside the tariff barrier. On the whole, the differential accorded the Canóvanas district is great enough so that the sugar industry in all probability will continue there in some form or other at least for the immediate future.

No attempt is made here to predict long-term trends in land utilization, for a number of unsettled matters make the distant future too problematical. The excellence of Canóvanas land for sugar production is irrefutable, but the advisability of export agriculture for an over-populated island is controversial. A large proportion of the profits from the sugar industry goes to extra-insular stockholders and to Puerto Rican land owners. Primitive natives supply an abundance of labor, but they live at a

bare subsistence level. There is great need for the improvement of the welfare of the laboring classes on the lowlands and the subsistence farmers in the mountains. The sugar company in the Canóvanas district has been active along this line, and the workers there are in better condition, both physically and socially, than the natives in the hill and mountain country. An ideal plan of land utilization would consider the best interests of all classes concerned, but planning is hampered by the uncertainty of the future. The confused political structure of Puerto Rico and the controversial nature of the issues before the government make it doubtful whether the ultimate choice will be some modification of the present system of corporate commercial agriculture or the development of an entirely new system of land tenure and management. The characteristics of land utilization in 1932, as recorded, analyzed, and interpreted in this study, represent one period in the geographic evolution of the Canóvanas district.

